SOME ASPECTS OF THE PHYSIOLOGICAL ONTOGENY OF STARCH, TOTAL SUGAR, PROTEIN, LEAF AND CORM OF *COLOCASIA ESCULENTA*

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INTRODUCTION

<u>Colocasia</u> <u>esculenta</u> (L.) Schott, taro or kalo as it is known in Hawaii is a member of the Arum family, Araceae. The Araceae family is composed of 100-105 genera and 1400-1500 species distributed primarily throughout the tropics and sub-tropics (5, 34). Taro found from sealevel to 7600 feet in the Punjab (73) appears throughout Asia, Africa, the Americas, and predominantly in the Pacific. India, the proposed origin of taro, has numerous wild types. There it is known as <u>Kachchi</u>, <u>Kachu</u> or <u>Arvi</u>. In Malaya it is called <u>Talla</u>, <u>Quloas</u> in Egypt, <u>Imo</u> in Japan, <u>Gabi</u> in the Philippines and as we move through the Pacific it is called <u>Darro</u> in Fiji, <u>Ta'o</u> in the Marquesas, <u>Talo</u> in Samoa, and <u>Kalo</u> or <u>Taro</u> in Hawaii and Tahiti (42, 74, 80).

Thriving in moist organic soil, preferring low-lying ground of swamps and streams, and growing just as well in areas of high rainfall or where water can be obtained in sufficient quantities, taro and its adaptive attributes have evolved into being one of the oldest cultivated crops of mankind. It is recorded as early as 100 B.C. in Chinese literature and by Pliny (23-70 A.D.). It was also recorded in early European Pacific explorations as being cultivated in Japan and New Zealand. Taro has always been recognized as a primary carbohydrate of the Pacific Islands. Taro and its cultivation and usage has perhaps reached its highest state of development in Hawaii. MacCaughey and Emerson (37) listed over 250 variety names with each serving a special purpose such as medicinal taro, poi taro, luau taro, and taro for fishing and ceremonial use only (80). In Hawaii, unlike most areas where it is cultivated, taro is propagated under two systems of management, the low-land or paddy system like rice and the dryland system in areas of high elevation and higher and more frequent rainfall. This dual system of management is still practiced here in Hawaii but on a much smaller scale. Over the past decade, taro has declined in popularity with the introduction of other carbohydrate sources that are in comparison more economical to produce, have a longer shelf life (like rice) and are easier to prepare in modern Hawaii. Comparing acreage and production for all the islands, there is a 50% drop in both. The 1948 record of Hawaiian dryland and wet taro acreage was 1,010 acres and that of 1964 was 470 acres for all the islands. The 1948 record for Hawaiian dryland and wet taro production for all the islands was also higher in 1964. It was 14.1 million pounds as compared to 9.2 million pounds in 1964 (71).

However, investigations (44, 45, 7) in the Pacific other than Hawaii have shown that taro is still one of the major carbohydrate sources in the diets of the people. The other staples are Mai'a (*Musa* spp); Ulu (*Artocarpus altilis*); Uala (*Impomea batatas*); Uhi, Ufi, or Pahui (*Dioscorea alata*); Fara, Ara or Hala (*Pandanus* spp); Niu (*Cocos nudifera*); Ape, Kape or Ta'amu (*Alocasia* spp); and Pia (*Tacca leontopetaloides*).

Because *C. esculenta* is a major carbohydrate source for the less developed islands of the Pacific, further investigations would be justified.

The objectives of this thesis are: 1) To record observations of plant growth and development as change in leaf number, leaf weight, leaf area, corm weight, cormel weight, number of cormels produced, protein content, and sugar content of corms and cormels; 2) To record the change in corm and cormel specific gravity and to determine if there is a relationship between corm starch and specific gravity; 3) To determine from the observations made some of the factors responsible for the variation in corm weight, corm starch content, and cormel starch content; 4) Identify and establish a collection of taro cultivars.

LITERATURE REVIEW

The cultural history and cultivation of taro is extensively covered (19, 20, 60, 37, 38, 80, 81). Spier (75) specifically traces the distribution of taro from Asia and concludes that the origin of taro is South Asia or Southeast Asia, with Assam as the locus of domestication according to linguistic data. Handy's (20) monograph on taro is perhaps the most comprehensive on the cultivation of taro throughout the islands of Hawaii. He covers the building of paddies, selection of sites, irrigation and mulching of taro. The ceremonial rituals that accompany the growth and cultivars of taro, the medicinal values and legends are included in Handy's (20) monograph.

Systematic descriptions of the taro varieties are limited, mostly to a descriptive list of color and form variation. Handy (20) lists 80 distinct cultivars in his monograph and believes that this list is just a part of the original large collection of taro in Hawaii. MacCaughey and Emerson (37-41) compiled a list of over 250 cultivar names of taro in Hawaii. A good systematic description of the cultivars was published in 1939 (80) where 84 different cultivars were described and applied to a key. One other systematic description of the cultivars of taro is from Japan where Kumazawa (30) provides a morphological description of 205 Far East cultivars and a review of the nomenclature of taro in Japan over the past 200 years.

Investigations of a horticultural nature

Prewal and Dargan (72) studied the effect of spacing on the development and yield of taro and observed that under Punjab conditions, spacing of 1.5 x 1.0 feet gave the most economical returns. They also were highly significant positive correlations between plant yield height, leaf area and height and leaf area.

Similar work was conducted by Moursi (60) in 1956 on the relationship of gaps or size of space between plants in stands or rows on yield of dasheen (oriental taro) grown in Egypt. Moursi had noticed the increase vigor of a plant when competitive stress was removed by the death of a neighboring plant in the stand. His experiment revealed no increase in yield by plots having more than two times the normal distance between plants within the stand to a point that equaled or bettered the yields of the control plots and plots with only two times the distance between plants.

Taro has been propagated asexually thru the centuries of its cultivation, while propagation by seeds has received little attention because taro has been observed to seldom set seed or that it is sterile (81). Abraham and Ramachandran (1) reported that sterility in _C. antiquorum_ was investigated by Maeda (43) and Banerji (6). Maeda (43) observed certain irregularities in the microsporogenesis of the plant and suggested that this may be the cause of sterility. Banerji (6) in a later paper reported that the degeneration of the female gametophyte may be responsible for sterility in _C. antiquorum_. Abraham and Ramachandran (1) investigated the microsporogenesis in _C. antiquorum_ and found that the abnormalities observed by Maeda (43) and Banerji (6) were rare and accountable by variations of temperature and other environmental factors and therefore could not account for the reported sterility.

Abraham and Ramachandran were able to obtain seeds of C. antiguorum and grow the developing embryo in culture.

A taro seed is described as resembling a miniature Japanese lantern, 1.2-1.5 mm in length, 0.7-1.0 mm in diameter, hard, straw colored and conspicuously longitudinally ridged (29).

A more rapid method of taro propagation than the usual huli (a slip consisting of one-eighth to one-fourth inch of the corm plus 6 to 12 inches of the basal portion of the petioles with the leaves removed) is described by Kikuta and Parris (28). The normally dormant buds (numbering 40-60 in a mature corm) borne in the leaf axils of the leaves on the surface of the corm are cut out and planted. Comparisons were made as to which of the two means of propagation had the most vigorous growth. Propagation by chemical stimulation of the dormant buds was found to be less successful than that obtained by mechanical means. In 1955, similar work was conducted by Moursi (57) using the "apical piece" (huli) and "corm" piece of two varieties of dasheen, Egyptian taro (C. antiquorum) and American taro (C. esculentum). Moursi found differences in germination and yield with the different propagating material, but no difference between the yields of the two varieties under Egyptian conditions.

Drought resistance among varieties of C. esculenta was studied by Gomi (18). He found variety difference in drought resistance and growth retardance when soil moisture was below 40 percent water holding capacity.

Fertilization and yield

There are not many papers on the effect of fertilizers on yield. The effect of potassium is reported to increase leaf number, to increase the weight of the leaf blade and petiole, the weight of roots, mother corms and cormels (58, 59, 25). Nitrogen applications will increase the yields of leaves, petioles, roots, mother corms and cormels to a level greater than potassium. Nitrogen and potassium applied together gave greater yields than either of them singly (25). Phosphorus is also reported to increase corm yields (11).

Disease of taro

Disease of corm and feeder roots are Pythium rot (also called soft rot, pala, or palahe), Hard rot (locally termed "guava seed"), Loliloli taro, and Sclerotium rot (63, 20). The control of Pythium rot caused by the yet unnamed fungus specie of Pythium is by exclusion of disease material or by drying and plowing up the soil between crops for 3 to 4 months (61, 62, 63, 64). All attempts to control Pythium rot with chemicals have failed. The Hard rot causal agent is unknown and no chemical control is recommended. Loliloli taro is reported to be a physiological disease caused by any stimuli which encourages rejuvenation of new growth and the withdrawal of starch from the corm. Sclerotium rot, a minor disease that is more prevalent in dryland taro, is caused by Sclerotium rolfsii, and is usually seen on over-mature plants. Control is difficult (63).

There are two major leaf diseases of taro here in Hawaii, Phytophthora spot and Phyllosticta spot. The appearance of

Phytophthora spot in the field caused by the downy mildew *Phytophthora colocasiae* is depended upon night temperature, humidity and light rain or heavy dew in the morning. Trujillo (78) gives the optimum night temperatures and humidity for sporulation, indirect germination and direct germination of zoosporangia in the field. Copper fungicide is reported to control Phytophthora spot and increase corm yields (79, 63). Copper fungicide is also recommended for the control of the fungi imperfecti, *Phyllosticta colocasiophila*, the causal agent of Phyllosticta spot. This leaf disease is reported to occur exclusively on upland taro and its appearance is also a function of weather, particularly cloudy, rainy weather for any protracted time, accompanied by cool winds (63). Attempts to find resistant varieties to these leaf diseases are reported in the literature of taro (63, 12, 61).

There are very few major insect pests of taro. There are reports of leaf hoppers and their biological control (46, 16).

Poi: chemical and microbial investigations

Poi is made from the cooked taro corm which is pounded into a paste, mixed with water to a desired consistency and eaten fresh or left to ferment until sour before eating. The manufacture, composition, and fermentation of poi has been investigated (2, 81, 65). Chemical investigations by Bilger and Young (8) on the fermentation process of poi by microbial organisms revealed reducing sugar, starch, volatile acids and nonvolatile acid contents at various stages of fermentation.

Some of the fermentation products found were lactic acid, acetic acid, formic acid, alcohol, acetaldehyde and carbon dioxide.

The microbial flora responsible for fermentation is reported to be a complex of species of Streptococcus and Lactobacillus which predominates during the first stage of fermentation and souring of the poi (2). During the second stage, the predominating flora is of the yeasts, mycoderms, oidia and contaminates from the poi factory (2, 17, 81). The fermentation products and the low pH values of poi as a result of the above poi microbes are cited as being responsible for the self sterilizing property of sour poi. Organisms of the colon-thyphoid-dysentery group (17) and Mycobacterium tuberculosis (22) are reported to be rendered harmless if the poi is left to sour for a prescribed time. Sour poi by the consensus of the investigators is the safest to eat (17, 22). Investigations of poi served in Hawaii's restaurants showed no presence of enteric pathogens (21). Poi is also reported to be used as an agar medium for the cultivation of Tubercle vacilli by Bushnell and Ichiriu (10).

Dental and Nutritional Value of Taro and Poi

Low percentages of dental cavities have been observed among those people of the Pacific whose diet is still native and use taro or poi as their carbohydrate (26, 32, 69). Just how the diets of these people reduce the incidence of dental caries is not clearly understood. The acid-base balance theory (81), is often given as the possible explanation of how the diets and the use of taro will reduce tooth decay. Larsen, et al. (33) conducted experiments where all other components of the experimental diets were held constant and varied the carbohydrate source between cereals, taro and potato. There were fewer dental caries with the potato-taro diet as compared to the cereal diet; a difference greater than 50 percent was shown. Larsen et al (33) concluded that the acid-base balance in itself was insufficient to account for the difference noted. Price (69) in 1935 conducted similar experiments in the South Sea Islands and although his results were similar, he concluded that the "alkalinity-acid" theory (acid-base balance) does not account for the good dental health of the South Sea Islanders. He believes instead it to be due to the mineral and activator content of the diet during the development of the child.

The nutritional value of taro was found to be higher in caloric and carbohydrate content than potato and brown rice, but slightly less for cooked white rice. The corm of taro is reported to be higher in vitamins A and B than rice and about equal to potato in B vitamins. Taro leaves, unlike taro corms are high in A and B vitamins and ascorbic acid, whereas taro corms are low in ascorbic acid. Taro leaves when cooked is depleted of its ascorbic acid. The mineral content of taro is comparable to that of potato and rice but exceed both in calcium. When compared to potato and the cereals, taro is deficient in protein, with the exception of rice (50, 51, 52, 53).

Digestibility of poi

Experiments on the digestibility of the raw starches of rice, taro, arrowroot and potato proved that taro and rice starch were the more easily assimilated. Taro assimilation was 98.8 percent. The size of the starch grains of taro was associated with its high digestibility (31).

Utilization of calcium and phosphorus of taro by young rats was found to be 90 percent as readily utilized by young rats as that of calcium acid phosphate salt, of the control diet (67). The utilization of calcium and phosphorus in rice and taro by young women (68), revealed that 80 percent of the calcium and 40 percent of the phosphorus in taro was assimilated and only 30 percent of the calcium and 35 percent of the phosphorus forms in rice was utilized. The conclusion was that the forms of calcium and phosphorus in taro is better utilized than that in rice.

Chemical composition

There has been a number of analyses made on the composition of taro and poi (8, 50, 64). Payne, *et al*. (65) analyzed air-dried, cooked taro of four varieties and found variation in composition among the varieties. The upland varieties had less starch but more complex sugars and ash than the lowland varieties. Inorganic qualitative and quantitative analysis also revealed that taro was higher in potassium in relation to the other minor elements.

Prophylaxis for allergy disease

The potential of poi as a prophylaxis for allergies to cereal products has raised considerable interest in reviving the taro industry in Hawaii (71). Taro or poi as a possible carbohydrate substitute for people allergic to cereals was mentioned by Alvarez in 1939 (3).

Feingold (15) reported that taro, C. esculenta, may be used as a milk substitute for children sensitive to cows milk. In 1967, Roth et al. (74) investigated the possible use of poi as an allergy food. The study was conducted in Hawaii with babies who had potential allergy reactions (babies with a family history of cereal allergy). The babies were restricted to a diet of either Soy milk or mother's milk and fed poi or a cereal at about six weeks old. The results of the investigations were: poi does not prevent allergies (babies who were fed poi were also prone to allergies), and that poi was well tolerated by babies and would be a good substitute in potentially allergic infants.

Oxalate content of taro

Taro cannot be eaten raw without subsequent irritation in the mouth and throat which is caused by the calcium oxalate that is present in all parts of the taro plant. Cooking will destroy the sharp crystals of calcium oxalate preventing irritation (65).

Physiological studies and oxalate content in taro and other plants were reported in two papers by Srivastava and Kreshiman in 1959 (76 and 77). In Colocasia the mature leaves have higher oxalate content than younger leaves and the leaves have greater oxalate content than the tubers. The oxalate in the plants once formed is reported to be used by the plant with difficulty and appears to be an end product that does not enter into metabolism of the plant. Srivastava and Kreshiman reported that the high soluble oxalate content in the leaves of Colocasia and

Alocasia may cause calcium deficiency and oxaluria if too many leaves are consumed as vegetables.

MATERIALS AND METHODS

Field experiment

The experiment was conducted on the Waimanalo Agriculture Experiment Station. The experimental area, consisting of a soil type of heavy rocky silty clay, was prepared for planting by first plowing in 400 lb/acre of P and laying out furrows two feet apart for irrigation.

On October 19, 1966 four commercial cultivars, 'Haakea' ('Haokea') 'Lehua Maoli', 'Piko Kea', and 'Red Moi' obtained from commercial growers, were planted according to a modified split-plot design with a systematic arrangement of whole plots (35). The main treatments (harvest periods) were not randomized but arranged in plots across the field. The harvest period of whole plots was composed of four sub-plots. To account for soil heterogeneity, the four taro cultivars were assigned randomly to the sub-plots. There were seven harvest periods and replications.

The field was bordered by another cultivar of taro, 'Bun long woo'. Slips of hulis (the ½ to ¼ inch piece of the top of the corm containing the apical meristem and eight to twelve inches of the leaf petiole) of the four commercial cultivars and the border row were planted six inches deep into the furrow and recessed six inches to the side of each furrow. Immediately after planting, 100 lb/acre of N and K were applied, followed by an application of Randox pre-emergence herbicide at 30 lbs/acre. Follow-up applications of fertilizers were 150 lb/acre of N and K at 1.5, 4.0, and 6.0 months after planting.

Irrigation was conducted three times a week and fungicide and insecticide applications were initiated upon the appearance of the first leaves.

Statistics and field design

The field design used was the systematic arrangement of field plots (1). This particular field design was used because of the introduction of error due to a border effect when a random sample is drawn from the experimental field population and because of the size of the population, almost all of the individuals in the population would be sampled. Periodic sampling necessary for growth studies would introduce this kind of error in a similar manner if the sample population is small and most of its individuals sampled. The systematic arrangement of whole plots deals with this problem because it is suitable for experiments where the randomization of dates of different harvesting periods for the study of growth may not be practical. This design is permissible where the whole plots are arranged systematically without randomization and interest is centered in the second series of treatment and the interaction with the whole plots (harvest periods). In this design there is no valid estimate of error for the main effect (whole plots) because the main plots were not randomized.

The analysis of variance and the degrees of freedom are shown on the following page.

Table 1. Degrees of freedom for analysis of variance by the systematic arrangement of whole plots.

Source of variation	d.f.
(28)Whole plots	27
Sub-plots	
(4)varieties	3
varieties x harvest	18
Error	63
Total	111

To examine the relationships among the data collected, stepwise multiple regression analysis was performed. The analysis was conducted on the computer program design by W. S. Yee for the IBM 7040, located at the Statistical and Computing Center of the University of Hawaii.

The program was designed to perform a regression output consisting of two parts. The first regression output consisted of the alpha (a) value of the dependent variable, the regression coefficient (b) and the t-test of the regression coefficient (t), the correlation coefficient (R), the analysis of variance of the regression line, the coefficient of determination, R^2 (that proportion of the total variability of the dependent variable that may be due to the effect of the independent variable), and the standard partial regression coefficient.

The second regression output called for the selection of the most significant variable and performing a complete regression output like that of the first step. The next most significant variable was then selected and the process repeated until the t-test value of the regression coefficient of the independent variable was less than 1.64.

The final outcome of the analysis was an estimate of the experimental regression line ($\hat{Y}$) by presenting to the investigator the most significant independent variables with regression coefficient values greater than 1.64 from his input of independent variables, the b_{xy} value of the significant independent variables, their t-test values, their r values, R^2 and the analysis of variance of the regression.

The Duncan range test was conducted to test the significance of differences between the harvest periods and varieties. The test, although it was recognized as invalid because of the field design where the harvest periods were not randomly but systematically arranged was conducted only to aid interpretation.

In the step-wise regression analysis, the determination of whether selected independent variables were significant contributors to the variation of the dependent variable was based upon the t-test of b, the F-test of the regression equation and the magnitude of its contribution. The significance of its contribution was tested by:

(1) Y (2,4) $SS_{2,4}$

(2) Y (2,) SS_2

$$\frac{\text{remainder}}{\text{residual } SS_{2,4}/n\text{-}m\text{-}1}$$

where: (1) equals the sum of squares due to regression in the stepwise analysis containing the variable (4) just introduced and whose contribution significance we wish to measure.

(2) equals the sum of squares due to regression in the step-wise analysis containing the variable or variables before the inclusion of the variable we are interested in.

remainder: $(SS_{2,4}) - (SS_2)$

residual $SS_{2,4}$/n-m-1: the residual sum of squares of SS_2, or the residual sum of squares of the variables or variables before the inclusion of the variable of interest.

n: the number of determinations

m: the number of variables in the step-wise regression of $SS_{2,4}$.

The test of significance is the F-test with 1 and n-m-1 degrees of freedom.

The t-test of the regression coefficient in determining the significance of the independent variable was based on n-m-1 degrees of freedom and not on 1.64 at infinite degrees of freedom as programmed.

Correlation analysis was also performed in the step-wise regression to determine similarity of growth patterns and possible information that may be of interest.

Plant material identification

Four commercial cultivars were obtained from island producers, 'Red Moi' from Mrs. William Kuluhiwa and 'Haakea' from Mr. Joseph Young (both from the island of Maui). 'Piko Kea' was obtained from Mr. C. Wong of Kahaluu, Oahu and 'Lehua Maoli' through Dr. Plucknett of the Kauai branch of the Hawaii Agriculture Experiment Station.

Taxonomic descriptions of 'Lehua Maoli', 'Piko Kea' and 'Haakea' ('Haokea') fit those provided by Whitney, et al. (80). There is no description of the cultivars named 'Red Moi' by Whitney, et al. (80) nor could it be keyed out to any other cultivar. A description of it is below.

'Red Moi'

Petiole: 60-120 centimeters long, light green in top half, bottom half has brown shading in a light green background fading into a light green as it moves to the top of the petiole, the cleft or sinus of the petiole is pink edged, the base of the petiole has a pink ring with a white zone between it and the remainder of the colored portions of the petiole.

Leaf blade: ovate, with acute lobes, shallow, narrow sinus of the lobes, medium texture, piko pale to colorless.

Corm: white flesh with yellow fibers, pink skin and pink shading in portions of corm near apex.

Collection of data

Taro is usually under vegetative growth for 4-5 months before corms are produced (11). Sampling of the plants for their corms, therefore, was initiated when the field of taro was four months in growth and sampling continued monthly (31 days) for eight samplings. Two plants were sampled per variety per replication for each sampling.

From each plant the number of cormels, number of corm leaves, the weight of corm leaves and the bulk weight of both corm and cormel leaves were recorded. Last leaves that were torn or chlorotic were not recorded because they were considered as non-contributing to the plant's growth. A leaf consisted of the petiole cut six inches up from the base and the leaf blade. To measure the change in leaf area during growth the area of an imaginary triangle of the first two leaves were taken. The height of the triangle was that distance from the piko (point where petiole is attached to the leaf blade) of the leaf to its tip and the base of the triangle was the distance of the line from the piko to the leaf edge perpendicular to the height of the triangle.

To estimate the specific gravity of the corms and cormels, the dry scaly covering and the leaf petioles were carefully removed leaving the apical meristem intact. The corms and cormels were then weighed and their volumes estimated by displacement in water. Specific gravity was then calculated from the formula: specific gravity = $\frac{\text{Mass}}{\text{Volume}}$

The corms and cormels were prepared for starch, total sugar and protein analysis by slicing them with a rotary meat slicer into waffers approximately 2 mm thick and drying them in a force draft oven at 85° C. for 12 hours. The dried waffers were then ground into a flour with a waring blender to a particle size of less than 60 mesh. The flour was then stored in air tight jars for analysis.

Procedures of analysis of percent protein, percent total sugar and starch

The procedure for the quantitative determination of starch and total sugar percentages in taro corms and cormels was a modified (13, 36, 49, 54, 55) technique of McCready *et al.*, 1950 (42). The method of analysis is based upon the color formed when anthrone reacts with the furfural derivatives produced by acid decomposition of sugars. The procedure is outlined below.

PROCEDURE FOR THE QUALITATIVE DETERMINATION OF
STARCH AND TOTAL SUGAR PERCENTAGE IN TARO CORMS

Extraction of Sugars

a. grind dried material to pass 60 - 80 mesh screen.

b. weigh 50 mg of the flour into a 50 ml centrifuge (calibrated) tube (The mixture before reading in the colorimeter should contain 0 - 40 ug of starch per mililiter.)

c. add a few drops of 80 percent alcohol to wet the flour and prevent clumping.

d. add 5 ml of water and stir.

e. add 25 ml of hot 80 percent alcohol and stir while the tubes are in hot water.

f. heat a minimum of 5 minutes and then centrifuge for about 5 minutes at 3000 rpm.

g. decant the alcohol and save for total sugar analysis.

h. repeat washing again, this time with 30 ml of hot 80 percent alcohol, heat, centrifuge, decant the alcohol and save for sugar analysis for a total of three washings.

Solubilizing the Starch Residue

a. to the residue in the calibrated centrifuge tubes add 5 ml water.

b. add 6 ml of 52 percent perchloric acid to the residue and stir occasionally over a period of 30 minutes for solubilization.

c. wash stirring rod with water into the centrifuge tube and centrifuge for 10 minutes at 3000 rmp, after adding 20 ml H_2O.

d. decant the aqueous starch solution after centrifuging into a 100 ml volumetric flask and solubilize again for 30 minutes; then without centrifuging, wash entire contents into the volumetric flask containing the first washing.

e. dilute to volume and filter thru clean glass wool, discarding the first 5 ml. (The solution may be kept in the refrigerator for as long as 48 hours, if necessary.)

Determination of Starch Content

a. dilute 5 ml of the filtered starch solution to 100 ml.

b. put 2 ml of diluted sample in test tube with 0.5 ml of 2 percent anthrone.

c. carefully "layer" 5 ml of concentrated sulfuric acid into the tube; then gently swirl until the ethyl acetate has hydrolysed as indicated by the appearance of a "floc" of anthrone; then swirl rapidly until the green color develops.

d. let it stand for 10 minutes until the green color develops.

e. read at 620 mu against a blank containing reagents and water.

Calculations for Percent Starch

a. prepare a standard curve from the reagents to be used in the starch determination with glucose concentrations per 2 ml of 0.0, 20 ug, 40 ug, and 80 ug. (Make up stock with 0.1 g glucose diluted to 100 and dilute to 100 ml aliquots of 4 ml, 2 ml, and 1 ml, giving 80 ug, 40 ug, and 20 ug per ml respectively; each must also contain 12 ml perchloric acid.)

b. from the optical density reading obtain the equivalent of glucose in grams from the standard curve and apply to the formula below.

$$\frac{\text{equivalent weight of glucose from standard curve} \times 0.90 \times 1000 \times 100}{\text{weight of sample (mg)}} = \%\ \text{starch}$$

0.90 = conversion factor for glucose to starch
1000 = dilution factor

Reagents for Starch Determination

a. 2 percent anthrone: dissolve 2 g anthrone in volumetric flask and bring to volume with ethyl acetate. Solubilize by heating. Store in amber bottle; it will keep for ca. two weeks.

b. 52 percent perchloric acid: Make from reagent grade.

c. Ethanol: 80 percent diluted from 95 percent stock.

d. Sulfuric acid 95 percent reagent grade.

TOTAL SUGAR ANALYSIS

Clarification of the Alcohol Sugar Extract

a. add 26.2 g cadmium sulphate ($3\ CdSO_4\ 8H_2O$) to 132 ml N H_2SO_4 and dilute to 1.0 L.

b. prepare a 0.55 N NaOH solution.

c. dilute the three alcoholic washings (total ca. 90.0 ml) to 100 ml.

d. to marked test tubes add 6 ml of the diluted alcohol washings, 6 ml of the cadmium sulphate-sulfuric acid mixture, and 3 ml of the 0.55 N NaOH solution.

e. heat the tubes in a boiling water bath for three minutes, cool to room temperature and filter through glass wool or centrifuge at 10,000 rpm for five minutes.

Determination of Total Sugar Content

a. take 2 ml of the cleared extract and place in marked acetone cleaned test tubes.

b. follow procedure as outlined previously for the determination of starch content.

Calculation of Total Sugar Percentage

a. compare optical density readings to standard curve from 0.0, 2 ug, 5 ug, 10 ug, and 20 ug of glucose.

b. apply glucose equivalents from standard curve to formula below:

$$\% \text{ Total Sugar} = \frac{\text{glucose equivalent in mg} \times 12.5 \times 100}{\text{weight of sample (mg)}}$$

12.5 = dilution factor

Materials for Percent Total Sugar Analysis

a. Cadmium Sulphate ($3\ CdSO_4\ 8H_2O$).

b. 1.0 N Sulfuric Acid

c. 0.55 N $NaOH$.

d. Glass wool.

Analysis for total protein

Determination of total protein content of dried corms and cormels was made from the conversion of percent total nitrogen by 6.25. Total percent nitrogen was determined by the micro-Kjeldahl method (48).

The data presented as corm and cormel starch, sugar and protein content are expressed as percent dry weight.

Cultivar collection

Plants collected for identification were planted in beds under wet land culture conditions in the Harold Lyon Arboretum. The plants were cared for and allowed to reach at least six months of growth before identification was made. This was necessary for the plants to show the particular characteristics which may not be present during the early stages of growth. Taro plants are so variable that this waiting period of six months also insured stability of their physical character. The plants were all identified and named according to Whitney *et al.*, 1939 (80).

RESULTS

Leaf area arising from corms

Leaf areas of the four taro cultivars show a downward trend with increasing age of the plant from five months after planting to eleven months. Analysis of variance revealed differences between cultivars in leaf area and no significant interaction: 'Piko Kea' had smaller leaves than 'Lehua Maoli', 'Haakea' and 'Red Moi'. 'Red Moi' had the largest leaf area. 'Lehua Maoli' and 'Haakea' were similar in leaf area (Table I). The mean leaf area values over the five to eleven month growth period of the cultivars were 50.5, 36.8, 63.7, and 51.3 square inches for 'Haakea', 'Piko Kea', 'Red Moi', and 'Lehua Maoli', respectively.

Leaf weight of corms

There were no differences between corm leaf mass of cultivars. The total mean leaf weight for the cultivars were 2.07 pound, 1.98 pound, 2.30 pound, and 1.90 pound for 'Haakea', 'Piko Kea', 'Red Moi', and 'Lehua Maoli', respectively.

Weight of corm leaves has a growth pattern similar to that of the corm leaf area. There was an identical peak at seven months followed by a sharp decline immediately afterward. 'Lehua Maoli', like the response in leaf area, had an earlier decline in corm leaf mass at six months of growth.

Leaf mass of corms and cormels

Analysis of variance revealed highly significant differences between cultivars but no interaction between harvest time and cultivars.

TABLE I. CHARACTERISTICS OF THE FOUR CULTIVARS

	'Lehua Maoli'	'Red Moi'	'Haakea'	'Piko Kea'
Corm leaf weight	-----	-----	-----	-----
Leaf mass (lb)	3.89a[1]	3.94a	4.16a	5.35b
Leaf area (m^2)	51.3 b	63.7 a	50.5 b	36.8 c
Corm leaf number	4.14ab	4.53a	4.00b	4.44a
Corm total sugar (Percent)	0.92a	0.92a	1.36b	1.39b
Cormel total sugar (Percent)	0.71b	0.72b	0.79b	1.01a
Corm starch (Percent)	74.7 a	71.6 a	58.6 b	64.2 b
Cormel starch	-----	-----	-----	-----
Corm total protein (Percent)	3.24b	3.80a	4.23a	4.32a
Cormel total protein (Percent)	2.67b	3.14b	3.13b	3.89a
Corm weight (Kg.)	1.658a	0.979b	0.906b	0.922b
Cormel weight (Kg.)	.139a	0.069b	0.080b	0.113a

[1] Figures with identical letters not different significantly. (Duncan test significant at 5%).

Duncan's test revealed that 'Piko Kea' had the largest leaf bulk and that there were no differences between the other cultivars (Table I). Total leaf bulk of the cultivars were 5.35 pound, 4.16 pound, 3.94 pound, and 3.89 pound for 'Piko Kea', 'Haakea', 'Red Moi', and 'Lehua Maoli', respectively (Table II).

Corm leaf number

Number of corm leaves per plant in each of the four varieties reduced with age (Table III). Some plants had no corm leaves at eleven months and later. The average number of corm leaves for the four cultivars were 4.04, 4.45, 4.54, and 4.15 for 'Haakea', 'Piko Kea', 'Red Moi', and 'Lehua Maoli', respectively. Corm leaf number was not significantly different between 'Red Moi', 'Piko Kea', and 'Lehua Maoli'. (Table I).

Cormel number

The number of cormels produced by each variety by the end of the experimental growth period was 39.5, 28.7, 15.5 and 12.7 for 'Piko Kea', 'Haakea', 'Red Moi', and 'Lehua Maoli', respectively (Table IV). Analysis of variance revealed no significant difference between cultivars in cormel number. The number of cormels continued to increase to the last sampling period in the varieties 'Piko Kea' and 'Haakea', while 'Lehua Maoli' and 'Red Moi' had reached their maximum number of cormels by the end of nine months of growth.

Cormel weight

Analysis of variance revealed highly significant differences between cultivars but no interaction effect at the five percent level

TABLE II. AVERAGE BULK[1] LEAF WEIGHT IN POUNDS PER CORM PLANT, FIVE MONTHS AFTER PLANTING

	MONTHS						
Cultivars	March	April	May	June	July	August	September
Haakea	2.93	3.98	6.09	4.75	4.88	3.78	3.11
Piko Kea	5.58	5.67	9.19	6.77	4.16	3.66	2.42
Red Moi	4.02	3.48	4.94	5.80	4.27	3.11	2.02
Lehua Maoli	5.05	5.63	5.19	4.32	3.44	2.19	1.47

[1]Bulk is the sum of corm and cormel leaf blade and petiole.

TABLE III. AVERAGE NUMBER OF CORM LEAVES, FIVE MONTHS AFTER PLANTING

	MONTHS						
Cultivar	March	April	May	June	July	August	September
Haakea	4.88	4.50	4.38	3.88	4.13	3.38	2.88
Piko Kea	6.63	5.13	5.75	4.13	4.00	2.88	2.63
Red Moi	5.13	4.63	5.38	4.63	4.25	4.38	3.38
Lehua Maoli	4.63	5.13	4.00	4.31	4.00	3.38	3.63

TABLE IV. AVERAGE NUMBER OF CORMELS PRODUCED PER PLANT

	MONTHS						
Cultivars	March	April	May	June	July	August	September
Haakea	4.75	7.50	11.89	14.00	12.63	15.38	28.75
Piko Kea	9.13	12.00	17.00	13.31	16.88	22.88	39.50
Red Moi	7.00	7.38	11.89	15.38	16.25	14.50	15.50
Lehua Maoli	18.00	13.00	14.25	13.82	15.75	14.13	12.75

of significance (Table V). The Duncan multiple range test (Table I) revealed that 'Lehua Maoli' and 'Piko Kea' were not different in weight but was significantly greater than the remaining two cultivars. 'Red Moi' and 'Haakea' had cormel weights that were not significantly different (Table I).

Corm weight

Analysis of variance revealed highly significant differences between cultivars and a significant interaction at the five percent level between varieties and harvest periods (Table VI).

'Lehua Maoli', 'Red Moi', and 'Haakea' all increased their corm weight from five to eleven months of age. On the contrary, 'Piko Kea' at seven to eleven months of growth did not increase its corm weight (Table VI).

'Lehua Maoli' had the highest average corm weight over the eleven-month growth period with 1658 grams. 'Red Moi' had a corm weight of 979 grams, and 'Haakea' and 'Piko Kea' had corm weights of 906 grams and 922 grams, respectively (Table I).

Percent corm total sugar content

Analysis of variance revealed that the interaction of age and cultivar on percent corm total sugar content was significant at the one percent level (Table VII). Analysis of variance also revealed differences between cultivar in total sugar content.

The curves of the percent corm total sugar content of 'Haakea', 'Red Moi' and 'Lehua Maoli' show a trend of sugar content curving downward from five to seven months, then curving up again over nine

TABLE V. AVERAGE THIRTY-ONE DAY INTERVAL WEIGHT (G.) OF CORMELS

Cultivars	MONTHS						
	March	April	May	June	July	August	September
Haakea	16.2	34.1	46.0	53.1	108.3	119.8	189.5
Piko Kea	31.5	55.5	133.7	105.0	108.4	153.0	221.6
Red Moi	19.2	30.1	24.9	50.3	68.3	122.8	175.2
Lehua Maoli	50.6	67.5	122.8	128.7	136.0	233.7	245.2

TABLE VI. AVERAGE THIRTY-ONE DAY INTERVAL CORM YIELDS (G.) FIVE MONTHS AFTER PLANTING

Cultivars	MONTHS						
	March	April	May	June	July	August	September
Haakea	493.1	535.3	723.1	913.5	828.4	1482.1	1619.0
Piko Kea	785.6	573.1	1175.6	1118.2	875.0	1123.1	1199.9
Red Moi	339.5	360.5	629.0	1053.3	1201.9	1475.6	1682.2
Lehua Maoli	1141.1	1076.7	1656.6	1868.0	1958.6	2438.6	1999.8

TABLE VII. PERCENT CORM TOTAL SUGAR ON DRY WEIGHT BASIS FOR THE FOUR CULTIVARS

Cultivars	MONTHS						
	March	April	May	June	July	August	September
Lehua Maoli	1.10	0.60	0.63	0.91	0.87	1.19	1.14
Piko Kea	1.50	1.05	0.74	1.27	1.50	1.41	2.24
Haakea	1.71	0.83	1.20	1.54	1.60	1.36	1.27
Red Moi	1.03	0.83	0.91	0.93	1.03	0.92	0.83

months and down through ten and eleven months of growth. 'Piko Kea' percent corm total sugar content growth curve behaves similarly except at eleven months of growth where there was a great increase to 2.4 in percent corm total sugar. The percent corm total sugar content of the cultivars, except for 'Piko Kea', during eleven months of growth ranged between 0.5 percent and 1.5 percent.

The average of the total sugar content were 0.92 percent, 1.39 percent, 1.36 percent, and 0.92 percent for 'Lehua Maoli', 'Piko Kea', 'Haakea', and 'Red Moi', respectively. The Duncan range test revealed that 'Piko Kea' and 'Haakea' were not different in total sugar content (Table I). 'Lehua Maoli' and 'Piko Kea' and 'Haakea' as a group had a total sugar content greater than 'Lehua Maoli' and 'Red Moi' together.

Cormel total sugar content

The data collected on the sugar content in the cormels revealed highly significant differences between the cultivars. The sugar levels at different stages of growth was also found to vary significantly between the cultivars. The interaction of harvest period and variety was significant at the five percent level (Table VIII).

The general percent cormel total sugar content trend was a drop in percent sugar from five to six months of growth moving upward over seven months and down to nine months and then moved upward a slightly at eleven months of growth (Table VIII). The different responses by 'Lehua Maoli' and 'Piko Kea' at various stages of growth may be responsible for the significant interaction. From six to nine months

TABLE VIII. PERCENT CORMEL TOTAL SUGAR ON DRY WEIGHT BASIS OF THE FOUR CULTIVARS

Cultivars	MONTHS March	April	May	June	July	August	September
Lehua Maoli	1.26	0.56	0.57	0.53	0.52	0.77	0.77
Piko Kea	1.39	0.54	1.35	0.97	1.04	0.94	1.36
Haakea	1.10	0.56	1.06	0.97	0.56	0.58	0.69
Red Moi	1.04	0.42	0.78	0.97	0.61	0.58	0.69

of growth the percent sugar content of 'Lehua Maoli' was constant before rising at ten months. 'Piko Kea' unlike 'Haakea' and 'Red Moi' did not drop in sugar content, but remained relatively constant from seven-ten months with an increase at eleven months.

The average total sugar contents of the four cultivars were 1.01 percent, 0.79 percent, 0.73 percent, and 0.71 percent for 'Piko Kea', 'Haakea', 'Red Moi', and 'Lehua Maoli', respectively. The Duncan range test revealed that 'Piko Kea' had the highest percent cormel total sugar and that the percent total sugars between the remaining cultivars were not significantly different (Table I).

Percent corm starch

Analysis of variance revealed significant differences between cultivars. The Duncan range test revealed that there was no difference between 'Lehua Maoli' and 'Red Moi' as a group and no difference between 'Piko Kea' and 'Haakea' as a group, but that 'Lehua Maoli' and 'Red Moi' had significantly higher starch percentages than 'Piko Kea' and 'Haakea' (Table I).

The Duncan multiple range test was performed on the percent starch content of the corms over time irrespective of the cultivars since the interaction of time and variety on percent starch was insignificant (Table IX). The test revealed a difference between five and eleven months of growth. There were no differences between the starch percentages of the remaining periods of growth.

TABLE IX. DUNCAN MULTIPLE RANGE TEST OF PERCENT CORM STARCH CONTENT ACROSS CULTIVARS (SIGNIFICANCE AT FIVE PERCENT)

	MONTHS						
	March	April	May	Sept.	July	Aug.	June
Percent starch	62.3a[1]	65.5ab	67.1ab	68.3ab	68.9ab	66.8ab	73.5b

[1]Figures with the same letter are non-significantly different.

Percent cormel starch

Analysis of variance revealed significant differences between the cultivars. The cormels of 'Lehua Maoli', 'Piko Kea' and 'Red Moi' were not different in their starch percentages. 'Haakea' had a smaller starch percentage than the other cultivars (Table XII).

The Duncan multiple range test performed on harvest periods across cultivars revealed no differences between the starch percentages of the seven harvest periods (Table I).

Specific gravity

Corm specific gravity

There were no significant differences between cultivars nor a significant interaction between cultivars and age. The mean specific gravity across cultivars was 1.0106. The mean specific gravity within cultivars were 1.021, 0.9890, and 1.0360 for 'Haakea', 'Piko Kea', 'Red Moi', and 'Lehua Maoli', respectively.

Cormel specific gravity

Test of the differences between cultivars was not significant. The interaction of cultivars and age was not significant at the five per cent level.

The specific gravity within cultivars was 1.0523, 1.0273, 1.0790, and 1.0547 for 'Haakea', 'Piko Kea', 'Red Moi' and 'Lehua Maoli', respectively.

Protein Content

Percent total corm protein content

The interaction of cultivars and age was not significant. The difference between cultivars was significant. A test for significant differences between the cultivars revealed that 'Piko Kea', 'Haakea' and 'Red Moi' were similar in total protein content and that 'Red Moi' and 'Lehua Maoli' were likewise, similar in content; although 'Lehua Maoli' was significantly lower than 'Piko Kea' and 'Haakea' in total protein (Table I).

The mean protein content among harvest periods irrespective of cultivars was higher in the fifth and sixth months of growth (Table X).

Percent total cormel protein content

Analysis of variance revealed that the interaction between cultivars and time was not significant. The protein content of the cultivars were significantly different (Table I).

TABLE X. DUNCAN MULTIPLE RANGE TEST OF PERCENT TOTAL PROTEIN AMONG THE SEVEN HARVEST PERIODS

	HARVEST PERIODS						
	MONTHS						
% Protein	March	April	May	June	July	Aug.	Sept.
Corms	4.38a[1]	4.76a	4.08ab	3.28b	3.51b	3.43b	3.19b
Cormels	4.66a	4.15a	2.58b	2.58b	2.55b	2.51b	2.47b

[1]Figures with identical letters are non-significantly different.

'Piko Kea' had the highest protein content (Table I). The remaining cultivars were not different significantly in their protein content.

The Duncan range test conducted among harvest periods revealed that total protein content decreased from the fifth and sixth months of growth. Total protein content there after did not decrease but remained at a constant low level of about 2.5 percent (Table X).

Minimum and Maximum Temperature

Minimum and maximum temperatures over a 24-hour period were recorded daily on a hygro-thermograph. The results in Figure 1 represent the average minimum and maximum temperature of 31-day intervals during the sampling period from March to September 1967. Maximum and minimum temperatures increased from March to September with the exception of July when there was a drop in maximum and minimum temperature.

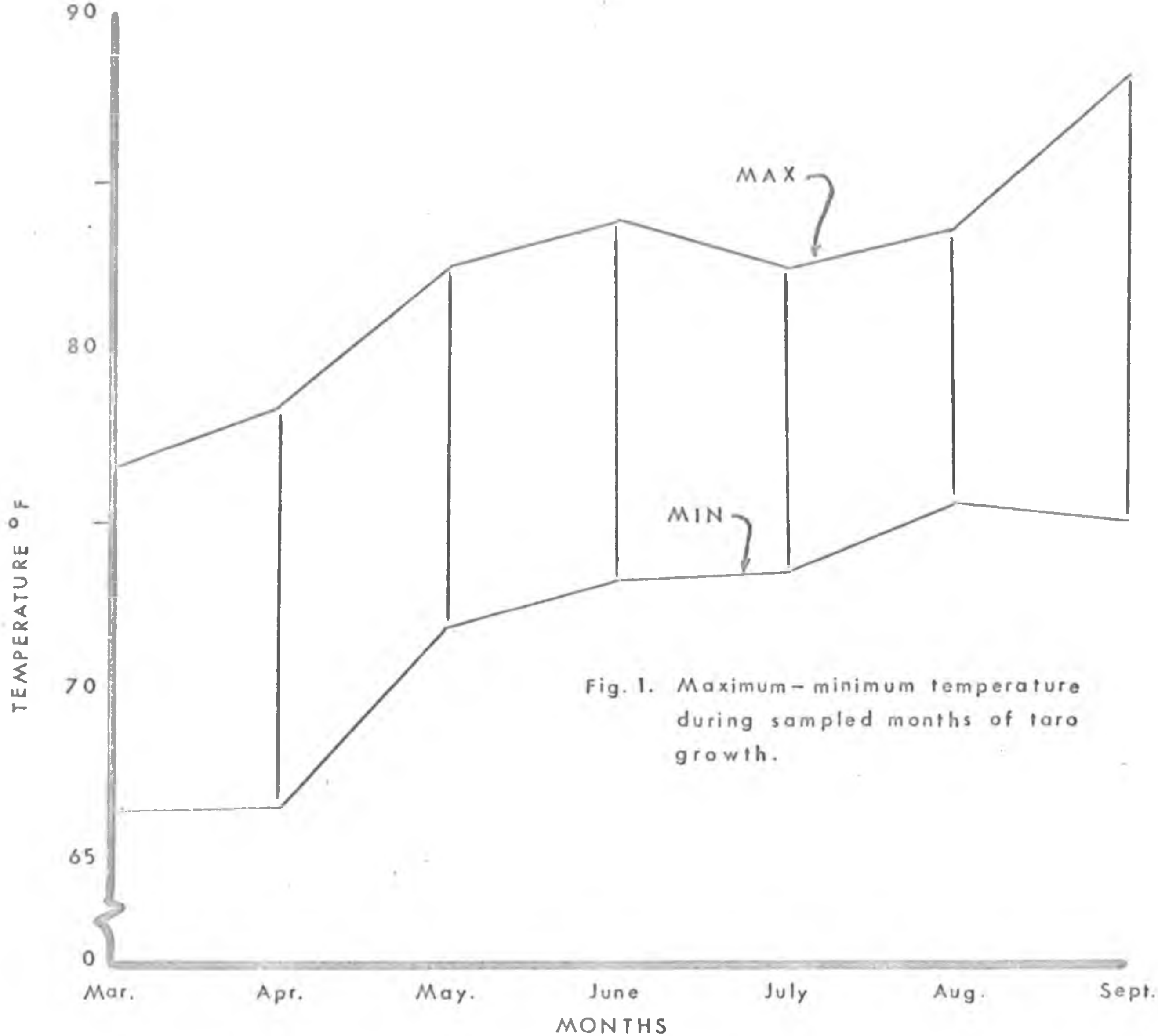

Fig. 1. Maximum – minimum temperature during sampled months of taro growth.

Regression and Correlation Results

Corm leaf area, corm weight, corm leaf mass, leaf bulk, percent corm starch and percent sugar content, corm specific gravity, percent corm protein content, percent cormel starch and percent sugar content, maximum and minimum temperature and age or time of harvest were used as variables in the regression and correlation analysis. Variables used as dependent variables in the regression analysis were corm weight, corm starch and cormel starch, and corm specific gravity. A separate analysis was performed on these dependent variables for each variety.

Corm weight

Correlation regression analysis of corm weight for each cultivar is presented in Tables XI to XIV. In Table XV, the significant variables contributing to the variation of 'Haakea' corm weight in the stepwise regression analysis are presented. The first stepwise regression analysis of 'Haakea' corm weight selected age of the corm as the first and largest contributor to corm weight, with R^2=.676. In the second stepwise regression analysis percent corm total sugar was selected as the next largest contributor of variation. The coefficient of determination value due to age and percent corm total sugar in the second step was R^2=.749. In the third step of the stepwise analysis percent total cormel sugar content was selected as the last significant factor in 'Haakea' corm weight. The R^2 for the three variables was .791.

TABLE XI. INTERACTION OF FACTORS AFFECTING CORM WEIGHT OF 'HAAKEA', FIRST REGRESSION OUTPUT

N = 28 d.f. = 12, 15 a = 1865.8900 F = 10.1112 R^2 = .889

Variables	b	t	* b^1	R
Corm leaf area	- 10.8796	1.52	-0.407	-0.669
Corm leaf mass	318.8510	2.10	0.617	-0.436
Leaf bulk	-121.6410	2.44	-0.369	-0.051
Percent corm starch	.7554	.10	0.021	-0.047
Percent total corm sugar	-799.9430	3.11	-0.52	-0.250
Corm specific gravity	125.5020	.12	0.015	-0.031
Maximum temperature	- 69.2918	1.58	-0.477	0.772
Minimum temperature	56.5476	1.17	0.365	0.745
Percent corm protein	- 64.5144	1.45	-0.196	-0.558
Percent cormel starch	- 2.2656	.45	-0.086	-0.024
Percent cormel total sugar	526.9880	2.22	0.322	-0.036
Age	236.9100	2.07	0.892	0.822

*b^1 = standard partial regression coefficient.

TABLE XII. INTERACTION OF FACTORS AFFECTING CORM WEIGHT OF 'PIKO KEA', FIRST REGRESSION OUTPUT

N = 28 d.f. = 12, 15 a = -1969.00 F = 10.3739 R^2 = 0.892463

Variables	b	t	b^1 *	R
Corm leaf area	- 7.7122	0.85	-0.450	-0.300
Corm leaf mass	70.3400	0.72	0.279	-0.246
Leaf bulk	52.5057	1.84	0.386	0.148
Percent corm starch	- 3.9509	0.62	-0.106	0.229
Percent corm total sugar	- 282.6720	1.90	-0.426	0.307
Corm specific gravity	1473.3300	1.64	0.153	0.072
Maximum temperature	- 5.8792	1.72	-0.255	0.627
Minimum temperature	23.1913	0.56	0.883	0.636
Percent corm protein	- 15.6156	0.54	-0.061	-0.020
Percent cormel starch	- 5.6699	1.35	-0.015	0.308
Percent cormel total sugar	97.1484	0.65	0.088	0.131
Age	139.7810	2.65	0.773	0.703

* b^1 = standard partial regression coefficient.

TABLE XIII. INTERACTION OF FACTORS AFFECTING CORM WEIGHT OF 'RED MOI', FIRST REGRESSION OUTPUT

$N = 28$ d.f. = 12, 15 $a = -5480.85$ $F = 4.18024$ $R^2 = 0.769808$

Variables	b	t	b^1 *	R
Corm leaf area	- 14.8524	-1.90	-0.647	-0.660
Corm leaf mass	- 13.7058	-0.06	-0.028	-0.547
Leaf bulk	86.6366	0.64	0.268	-0.161
Percent corm starch	15.8439	0.95	0.237	0.430
Percent corm total sugar	574.0290	0.76	0.146	-0.191
Corm specific gravity	- 18.6448	-0.02	-0.004	0.322
Maximum temperature	15.4012	0.29	0.103	0.780
Minimum temperature	59.6192	1.09	0.377	0.778
Percent corm protein	62.8819	0.65	0.134	-0.504
Percent cormel starch	- 4.5889	-0.68	-0.126	0.220
Percent cormel total starch	- 40.6183	-0.11	-0.019	-0.219
Age	2.027	0.22	0.050	0.275

* b^1 = standard partial regression coefficient.

TABLE XIV. INTERACTION OF FACTORS AFFECTING CORM WEIGHT OF 'LEHUA MAOLI', FIRST REGRESSION OUTPUT

N = 28 d.f. = 12, 15 a = 3762.6400 F = 21.2674 $R^2 = 0.944487$

Variables	b	t	b^1 *	R
Corm leaf area	- 5.5317	-0.64	-0.262	-0.820
Corm leaf mass	- 110.4650	-0.65	-0.222	-0.822
Leaf bulk	229.1070	3.39	0.641	-0.578
Percent corm starch	6.1905	1.15	0.095	0.281
Percent corm total sugar	200.7720	1.02	0.508	0.092
Corm specific gravity	2649.2800	1.18	0.581	-0.073
Maximum temperature	- 88.0314	-3.00	-0.558	0.782
Minimum temperature	105.8080	3.07	0.629	0.909
Percent corm protein	17.3946	0.23	0.018	0.105
Percent cormel starch	- 5.2940	-0.91	-0.093	0.474
Percent cormel total sugar	- 384.7270	-1.53	-0.215	-0.357
Age	239.5330	2.78	0.834	0.858

* b^1 = standard partial regression coefficient.

TABLE XV. INTERACTION OF SIGNIFICANT FACTORS IN THE CORM WEIGHT OF 'HAAKEA'

N = 28 d.f. = 3, 24 a = -323.327 R^2 = 0.791797

Variables	b	t	$^*b^1$
Percent total corm sugar	-725.8470	3.60	-0.477
Percent total cormel sugar	478.0850	2.20	0.292
Age	220.2750	8.90	0.829

$^*b^1$ = standard partial regression coefficient.

The significant variables affecting the corm weight of 'Piko Kea' were leaf bulk, percent corm sugar, corm specific gravity, maximum temperature, percent cormel starch content and age (Table XVI). The first significant variable selected out in the stepwise regression analysis was age with R^2=.495. Leaf bulk was the second significant variable, with an R^2=.772, an increase of 27.7 percent. In the next four successive steps maximum temperature, percent corm total sugar, corm specific gravity and percent cormel starch content contributed to the variation in 'Piko Kea' corm weight in this order of magnitude. The respective increase in R^2 in the order of their appearance was 3.9 percent, 3.4 percent, 1.9 percent, and 1.6 percent.

The number of significant variables affecting the corm weight of 'Red Moi' was fewer than those of 'Piko Kea'. The contribution of each variable (Table XVII) in order of their appearance in the stepwise

TABLE XVI. INTERACTION OF SIGNIFICANT FACTORS IN THE CORM WEIGHT OF 'PIKO KEA'

N = 28 d.f. = 6, 21 a = -2351.020 R^2 = 0.880921

Variables	b	t	b^{1} *
Leaf bulk	53.6973	3.64	0.395
Percent total corm sugar	- 215.2780	-2.78	-0.324
Corm specific gravity	1455.6500	1.96	0.151
Maximum temperature	10.1812	3.82	0.441
Percent cormel starch	- 5.6693	-1.68	-0.142
Age	174.6700	8.86	0.967

* b^{1} = standard partial regression coefficient.

TABLE XVII. INTERACTION OF SIGNIFICANT FACTORS IN THE CORM WEIGHT OF 'RED MOI'

N = 28 d.f. = 4, 23 a = -4291.6200 R^2 = 0.731478

Variables	b	t	b^{1} *
Corm leaf area	-13.5240	-2.76	-0.589
Leaf bulk	96.1266	1.79	0.297
Maximum temperature	9.0903	0.21	0.061
Minimum temperature	69.4744	1.76	0.439

* b^{1} = standard partial regression coefficient.

regression analysis to R^2 were 60.9 percent, 4.2 percent, 4.4 percent and 3.6 percent for maximum temperature, corm leaf area, leaf bulk, and minimum temperature.

Minimum temperature and percent corm protein content (Table XVIII) were the significant variables selected from the stepwise regression analysis of 'Lehua Maoli'. Minimum temperature made the largest contribution to R^2 with a value of R^2=.826.

TABLE XVIII. INTERACTION OF SIGNIFICANT FACTORS IN THE CORM WEIGHT OF 'LEHUA MAOLI'

N = 28 d.f. = 2, 25 a = -9906.1100 R^2 = 0.853920

Variables	b	t	b^{1}*
Minimum temperature	153.8360	12.00	0.919
Percent corm protein	157.6740	2.16	0.166

*b^{1} = standard partial regression coefficient.

<u>Percent corm starch content</u>

The first correlation regression analysis output of percent corm starch of 'Haakea' (Table XIX) accounted for R^2=.821 of the variation. Percent cormel starch content with an R^2=.743 was the only significant variable selected out in the stepwise regression analysis accounting for 90.5 percent of the R^2 in the first correlation regression output (Table XX).

TABLE XIX. INTERACTION OF FACTORS AFFECTING PERCENT CORM STARCH OF 'HAAKEA', FIRST REGRESSION OUTPUT

N = 28 d.f. = 13, 14 a = 55.7008 F = 4.96786 R^2 = 0.821842

Variables	b	t	b^1 *	R
Corm leaf area	- 0.0100	-0.03	-0.013	0.090
Corm weight	- 0.0721	-0.93	-2.533	-0.047
Corm leaf mass	5.7618	0.89	0.392	0.002
Leaf bulk	- 2.7373	-1.12	-0.291	-0.057
Corm and cormel yield	0.0676	0.96	2.602	-0.032
Percent corm total sugar	- 0.3172	-0.02	-0.007	0.118
Corm specific gravity	40.9551	1.09	0.176	0.164
Maximum temperature	- 1.4324	-0.82	-0.347	-0.026
Minimum temperature	0.6003	0.25	0.136	0.037
Percent corm protein	- 2.5434	-1.49	-0.272	-0.143
Percent cormel starch	0.5891	5.86	0.787	0.862
Percent cormel total sugar	3.8789	0.37	-0.833	0.131
Age	0.7186	0.13	0.095	-0.020

* b^1 = standard partial regression coefficient.

TABLE XX. INTERACTION OF SIGNIFICANT FACTORS OF 'HAAKEA' PERCENT CORM STARCH

N = 28 d.f. = 1, 26 a = 19.2873 R^2 = 0.743

Variables	b	t	b^{1*}
Percent cormel starch	0.6447	8.67	0.862

$^*b^1$ = standard partial regression coefficient.

In the first correlation regression analysis output of percent corm starch content of 'Piko Kea' R^2=.760 of the variation was accounted for by the variables listed in Table XXVII. The variables most significant in the variation of corm starch percentages in the stepwise regression (Table XXI) accounted for R^2=.547 of the variations. Percent cormel starch content was the first significant and largest contributor to corm starch content of 'Piko Kea'. The other significant variables were selected out in this order: percent corm sugar content, minimum temperature, and maximum temperature which increased the R^2 value of percent cormel starch by adding 11.5 percent, 6.3 percent, and 9.1 percent variation to the R^2, respectively.

The coefficient of determination of 'Red Moi' in the first correlation regression output accounted for 77.2 percent of the variation in percent corm starch content (Table XXV).

TABLE XXI. INTERACTION OF SIGNIFICANT FACTORS OF 'PIKO KEA' PERCENT CORM STARCH

N = 28 d.f. = 1, 26 a = 19.2873 R^2 = 0.743

Variables	b	t	b^{1}*
Percent corm total sugar	-8.2207	2.52	-0.458
Maximum temperature	-1.7866	2.15	-2.869
Minimum temperature	2.2318	2.37	3.146
Percent cormel starch	0.3191	2.02	0.317

*b^{1} = standard partial regression coefficient.

TABLE XXII. INTERACTION OF SIGNIFICANT FACTORS AFFECTING 'LEHUA MAOLI' PERCENT CORM STARCH

N = 28 d.f. = 1, 26 a = 47.1126 R^2 = 0.179

Variables	b	t	b^{1}*
Percent cormel starch	0.3677	2.38	0.424

*b^{1} = standard partial regression coefficient.

TABLE XXIII. INTERACTION OF SIGNIFICANT FACTORS OF 'RED MOI' PERCENT CORM STARCH

N = 28 d.f. = 4, 23 a = 35.8786 R^2 = 0.702

Variables	b	t	* b^1
Percent corm total sugar	-13.1224	-1.70	-0.224
Corm specific gravity	30.9861	3.62	0.470
Percent cormel starch	0.2222	3.28	0.410
Age	0.1243	1.70	0.207

* b^1 = standard partial regression coefficient.

TABLE XXIV. INTERACTION OF FACTORS AFFECTING 'PIKO KEA' PERCENT CORM STARCH, FIRST REGRESSION OUTPUT

N = 28   d.f. = 4, 23   a = 62.3942   F = 3.4186 R^2 = 0.7604

Variables	b	t	b^{1} *	R
Corm leaf area	-0.8795	-2.85	-1.903	0.017
Corm weight	-0.0061	-0.11	-0.226	0.229
Corm leaf mass	5.3827	1.38	0.792	0.077
Leaf bulk	1.7522	1.42	0.477	0.306
Corm and cormel yield	-0.0002	-0.005	-0.009	0.175
Percent corm total sugar	-0.0012	-1.88	-0.675	-0.416
Corm specific gravity	6.7768	0.12	0.026	0.024
Maximum temperature	-2.9215	-2.35	-4.691	0.077
Minimum temperature	3.9226	0.19	5.531	0.130
Percent corm protein	-0.1823	-0.15	-0.026	-0.085
Percent cormel starch	0.0508	0.24	0.050	0.527
Percent cormel total sugar	8.3095	1.11	0.280	-0.080
Age	-2.8171	-0.88	-0.577	0.012

* b^{1} = standard partial regression coefficient.

TABLE XXV. INTERACTION OF FACTORS AFFECTING 'RED MOI' PERCENT CORM STARCH, FIRST REGRESSION OUTPUT

N = 28 d.f. = 13, 14 A = 1.1254 F = 3.6625 R^2 = 0.7727

Variables	b	t	b^1 *	R
Corm leaf area	0.1795	1.42	0.423	-0.209
Corm weight	- 0.0045	-0.33	-0.303	0.430
Corm leaf mass	- 0.4960	-0.15	-0.069	-0.153
Leaf bulk	- 1.4486	-0.68	-0.299	0.109
Corm and cormel yield	0.0075	0.63	0.561	0.429
Percent corm total sugar	-18.5894	-1.73	-0.317	-0.395
Corm specific gravity	29.9893	2.95	0.455	0.667
Maximum temperature	0.0339	0.04	0.015	0.383
Minimum temperature	0.3652	0.42	0.154	0.322
Percent corm protein	1.1773	0.78	0.168	-0.236
Percent cormel starch	0.2326	2.73	0.429	0.540
Percent cormel total sugar	- 2.1419	-0.39	-0.070	-0.238
Age	0.1579	1.18	0.262	0.374

* b^1 = standard partial regression coefficient.

TABLE XXVI. INTERACTION OF FACTORS AFFECTING PERCENT CORM STARCH OF 'LEHUA MAOLI', FIRST REGRESSION OUTPUT

N = 28 d.f. = 13, 14 a = -9.0986 F = 1.1592 R^2 = 0.5184

Variables	b	t	b^1 *	R
Corm leaf area	- 0.1846	0.45	-0.569	-0.077
Corm weight	0.0146	1.24	0.952	0.281
Corm leaf mass	0.8352	0.98	1.094	-0.114
Leaf bulk	- 3.1526	-0.68	-0.574	0.077
Corm and cormel yield	0.0042	0.80	0.412	0.176
Percent corm total sugar	- 13.9374	-0.01	-2.295	0.088
Corm specific gravity	-172.2340	-0.01	-2.461	-0.137
Maximum temperature	3.6043	0.17	1.488	0.237
Minimum temperature	- 0.5134	-0.23	-0.199	0.251
Percent corm protein	2.6332	0.69	0.180	0.179
Percent cormel starch	0.4395	1.74	0.507	0.424
Percent cormel total sugar	27.9714	2.38	1.017	-0.093
Age	- 9.0342	-1.69	-2.046	0.140

* b^1 = standard partial regression coefficient.

TABLE XXVII. CORRELATED VARIABLES TO CORM SPECIFIC GRAVITY OF 'RED MOI' AND 'LEHUA MAOLI'

d.f. = 26

Variety	Variable	r	R^2
Red Moi	Corm starch content	.667**	.445
Lehua Maoli	Corm total sugar content	-.969**	.940

The variables considered most significant in the stepwise regression analysis for 'Red Moi' were corm specific gravity, percent cormel starch, age, and percent corm total sugar content, with R^2 values of .445, .595, .665, and .702, respectively in order of their inclusion in the stepwise regression (Table XXIII).

The total variation accounted for by the variables in Table XXVI accounted for R^2=.518 of the variation in percent corm starch content of 'Lehua Maoli'. Percent cormel starch content was the only variable selected by the stepwise regression that significantly contributed to the variation in 'Lehua Maoli' percent corm starch content Table XXII).

Corm specific gravity

Correlation analysis of corm specific gravity on percent corm starch content revealed that only in 'Red Moi' was corm specific gravity significantly correlated (Table XXVII). Corm specific gravity in 'Haakea' and 'Piko Kea' was not correlated to any of the variables tried. 'Lehua Maoli', unlike any of the others, had corm specific gravity correlated to percent corm total sugar.

Corm leaf mass

Leaf mass in all of the cultivars were significantly correlated to leaf area (Table XXVIII) and the sum of an average corm and an average cormel. The growth pattern of leaf mass of the cultivars was also correlated to corm yield, maximum and minimum temperature, and age, with the exception of 'Piko Kea' which was not correlated to age. The leaf mass of 'Red Moi' unlike the other cultivars was correlated to corm protein content. The leaf mass of 'Piko Kea' was the only exception that was correlated to corm sugar content.

Leaf bulk

Correlation analysis of leaf bulk was performed in the interest of its relationship to the development of taro. The two commonly significantly correlated variables to leaf weight were leaf area and age in all of the varieties but 'Haakea' (Table XXIX). The leaf bulk of 'Haakea' was found to be not correlated to any of the growth measurements. In 'Lehua Maoli' corm weight, corm and cormel yield, maximum and minimum temperature were also correlated to leaf bulk.

Percent cormel starch content

The percent cormel starch content of the four cultivars were correlated and regressed against the identical variables of percent corm starch content. Only the F-test of the regression line and the

TABLE XXVIII. SIGNIFICANTLY CORRELATED VARIABLES TO CORM LEAF WEIGHT.
L-A = Leaf Area; C-Y = Corm Yield; CC-Y = Corm and Cormel Yield;
Max. = Maximum temperature; Min. = Minimum temperature;
C-P = Corm Protein; C-S = Corm Sugar; Age.

N = 28

Variety	L-A	C-Y	CC-Y	Max.	Min.	Age	C-P	C-S
Haakea	.864	-.436	-.469	-.541	-.552	-.702	--	--
Piko Kea	.923	--	-.457	--	--	-.771	--	-.388
Red Moi	.859	-.547	-.549	-.582	-.530	--	.516	--
Lehua Maoli	.974	-.822	-.781	-.839	-.885	-.938	--	--

TABLE XXIX. CORRELATED VARIABLES TO LEAF BULK OF THE FOUR CULTIVARS

N = 28 d.f. = 1, 26

Variety	Variable	R
Haakea	-----	-----
Piko Kea	Leaf area	.765**
	Age	-.454**
Red Moi	Leaf area	.682**
	Age	.576**
Lehua Maoli	Leaf area	.906**
	Corm weight	-.578**
	Corm and cormel yield	-.584**
	Maximum temperature	-.716**
	Minimum temperature	-.723**
	Age	-.844**

coefficient of determination of the first regression output is presented in Table XXX.

Like the stepwise regression analysis performed on percent corm starch content (Tables XX, XXI) in reverse, percent corm starch content was the first and largest contributor to percent cormel starch variation in 'Haakea' and 'Piko Kea' (Tables XXXI, XXXII).

Percent corm starch of 'Red Moi' was the largest factor in percent cormel starch (Table XXXIII), although corm specific gravity was the largest factor in percent corm starch content (Table XXIII).

TABLE XXX. PERCENT CORMEL STARCH CONTENT; F-TEST VALUES OF TEST OF REGRESSION AND VALUES OF R^2, FIRST CORRELATION-REGRESSION OUTPUT

Variety	F	R^2
Haakea	4.20**	.795
Piko Kea	1.57 N.S.	.593
Red Moi	1.43 N.S.	.571
Lehua Maoli	2.15 N.S.	.666

TABLE XXXI. INTERACTION OF SIGNIFICANT FACTORS OF 'HAAKEA' PERCENT CORMEL STARCH CONTENT

N = 28 d.f. = 1, 26 a = -6.5540 f = 75.22** R^2 = 0.7431

Variable	b	t	* b^1
Percent corm starch	1.1527	8.67**	0.862

* b^1 = standard partial regression coefficient.

TABLE XXXII. INTERACTION OF SIGNIFICANT FACTORS OF 'PIKO KEA' PERCENT CORMEL STARCH CONTENT

N = 28 d.f. = 1, 26 a = 35.9647 F = 10.03** R^2 = 0.2784

Variable	b	t	* b^1
Percent corm starch	0.5251	3.16**	0.527

* b^1 = standard partial regression coefficient.

TABLE XXXIII. INTERACTION OF SIGNIFICANT FACTORS OF 'RED MOI' PERCENT CORMEL STARCH CONTENT

N = 28 d.f. = 2, 25 a = —62.1683 F = 9.36** R^2 = 0.4282

Variables	b	t	* b^1
Percent corm starch	1.2927	4.24**	0.540
Percent corm total sugar	43.4859	-2.44*	0.125

* b^1 = standard partial regression coefficient.

The largest contributing factor to variation in the percent cormel starch of 'Lehua Maoli' was percent cormel sugar content (Table XXXIV). The regression coefficient was negative indicating an increase in percent cormel starch with a decrease in percent cormel sugar content. The magnitude of influence by each significant variable in Table XXXIV is indicated by their partial standard regression coefficient, b^1.

TABLE XXXIV. INTERACTION OF SIGNIFICANT FACTORS OF 'LEHUA MAOLI' PERCENT CORMEL STARCH

N = 28 d.f. = 4, 23 a = 34.9766 F = 77.57** R^2 = 0.5743

Variables	b	t	* b^1
Corm and cormel yield	0.0033	1.88	0.361
Percent corm starch	0.3267	2.01	0.283
Percent corm protein	5.4406	2.30	0.322
Percent cormel total sugar	-0.0011	2.45	-0.361

* b^1 = standard partial regression coefficient.

Cultivar Collection

The majority of the plants collected was from an old collection in the Harold Lyon Arboretum. Other plants were collected from Maui, Oahu, and Kauai. Over a hundred plants were collected and planted and out of these plants 41 cultivars were selected as being distinctive and 32 were identified and named according to Whitney, et al., 1939.

Identification was often confusing and made difficult by the lack of distinct characteristics in many of the cultivars. A list of the identified cultivars and their hill numbers are presented below.

Hill		Hill	
2.	'Lauloa palakea papamu'	24.	'Lauloa eleele ula'
3.	'Niue ulaula'	25.	'Piko ulaula'
5.	'Manini toretore'	26.	'Akado'
6.	'Manini owalii'	27.	'Miyako'
8.	'Lehua keokeo'	29.	'Tusuronoko'
9.	'Lehua apei'	30.	'Lauloa eleele omao'
10.	'Apuwai'	31.	'Mana okoa'
11.	'Leo'	32.	'Mana opelu'
12.	'Eleele makoko'	34.	'Mana ulu'
13.	'Lauloa keokeo'	35.	'Bun Long Woo'
14.	'Ulaula poni'	36.	'Waihiwa'
15.	'Maea'	37.	'Lauloa palakea ula'
18.	'Manini uliuli'	44.	'Ulaula kumu'
20.	'Mana piko'	45.	'Haakea' ('Haokea')
21.	'Lauloa palakea eleele'	46.	'Piko Kea'
23.	'Ulaula moana'	49.	'Niue'

DISCUSSION

The average corm weight, percent corm starch, percent corm total sugar, percent corm protein content, corm leaf area and leaf bulk of the four cultivars are presented in Figure 2 as a summarized growth picture of taro grown under dryland culture at the Waimanalo Experiment Station.

The development of taro begins with a rapid increase in vegetative growth and in corm weight (12). The vegetative stage for this experiment occurred from the time of planting to six months of growth. The second stage, corm production, was initiated at four to five months after planting.

The change from a vegetative stage of leaf growth to a stage of corm growth during the observed five to eleven months of growth period was recorded as a reduction in top growth or leaf bulk and a simultaneous increase in corm weight (Fig. 2), cormel weight and cormel number. The change in leaf bulk was the result of an increase from five to six months and then a decrease to eleven months of growth in corm leaf weight, corm leaf area and cormel leaf weight. This was accompanied by a reduction in plant height and no further increase in leaf number. The reduction in plant height is related to the change in leaf weight. Leaf weight is the weight of the corm leaf blade and leaf petiole which change in weight through a change in length and girth.

Leaf bulk was positively correlated to corm leaf area from five to eleven months of growth (Table XXIX) in all of the cultivars but

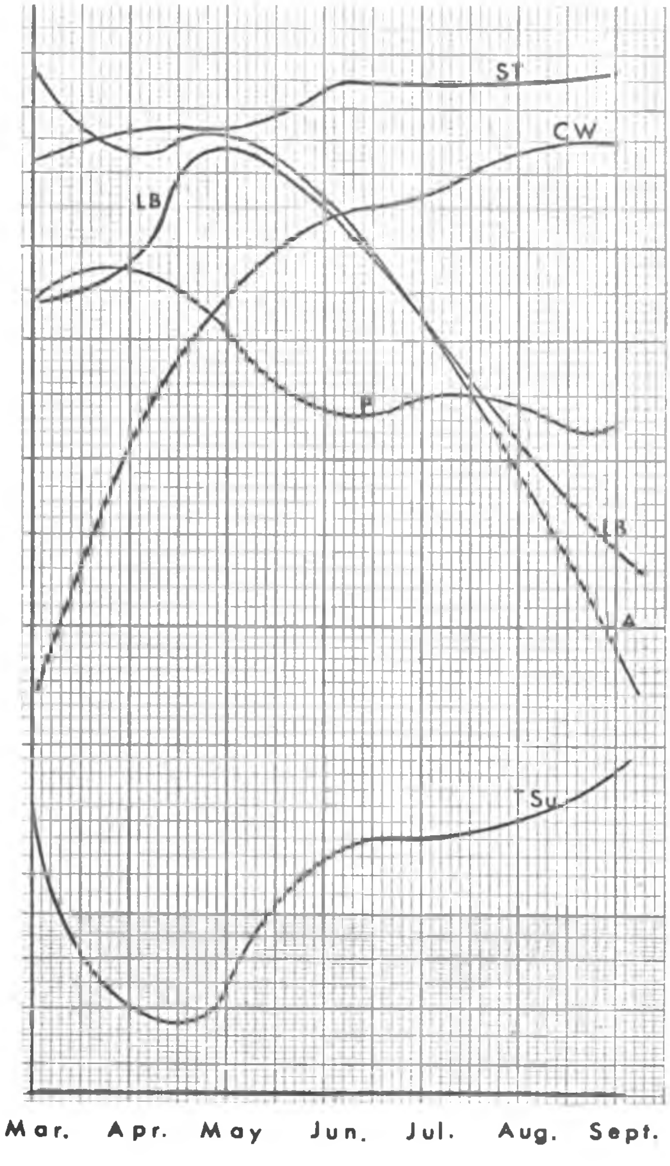

Fig. 2. General growth curve of the four cultivars. ST=% corm starch, CW= corm weight (g), LB=leaf bulk (lb.), P=% corm protein, LA = leaf area (in^2), TSu=% total sugar

'Haakea'. Age was negatively correlated to leaf bulk to all of the cultivars but 'Haakea' (Table XXIX). If observations were recorded during the one to five months of growth, the curve for leaf bulk over the eleven month period would be curvilinear. The five to eleven month observations of growth for 'Haakea' may be curvilinear (Fig. 2); therefore, there would be no correlation between leaf bulk and age of 'Haakea'. The difference within cultivars in the development of cormel leaf weight and corm leaf weight may alter the curve formed by leaf bulk. Cormel leaf weight may be increasing while corm leaf weight may have had reached its maximum. Thus cormel leaf weight may maintain the leaf bulk curve until cormel leaf weight attains its maximum. This may be the cause of the lack of correlation between leaf bulk and leaf area of 'Haakea'. It may also explain the correlation of 'Lehua Maoli' to corm weight, corm and cormel yield and maximum and minimum temperature and the lack of correlation with these variables with leaf bulk of 'Haakea', 'Piko Kea' and 'Red Moi.

Leaf weight has a growth curve similar to that of leaf bulk. The reduction in leaf weight was due to a decrease in leaf area of the blade and the shortening of the leaf petiole.

It was observed that there was an increase in leaf number during the one to five months of growth. From the recorded five to eleven months of growth (Table III) corm leaf number was constant from five to eight months before declining from nine months to the last sampling. Moursi (60) reported that the number of leaves of dasheen increased to a point in time where leaf number was constant. This was associated with the change in growth of the dasheens from a vegetative stage to a reproductive stage, where a great proportion of organic constituents were transferred to the corms. Moursi (57, 60) and Izawa and Okamoto (25) also stated that leaf area, leaf weight and petiole weight of dasheen decreased while the corm and cormel weight increased. In 1959, Izawa and Okamoto (26) during their observations of the effect of N, P, and K on the organic constituents of sweetpotato during growth noticed that the growth of the leaves, petioles and stems had attained their maximum midway during the growing season while the growth of the tuber continued. Reports by Moursi (57, 60) and Izawa and Okamoto (25) on dasheen further substantiate the leaf bulk-corm weight growth curve of Figure 2. In potato, the leaf area growth curve is bell shaped with time and tuber weight continued to increase as leaf area decreased (24).

The percent corm total sugar content (Figure 2) decreased from five months of growth to six months of growth before increasing again slowly to eleven months, while corm weight and percent corm starch continued to increase from five to eleven months. The percent total sugar content of the corm may or may not represent the concentration of sugars translocated from the leaf in the form of sucrose (25, 10) to be used in starch synthesis. The percent corm total sugar content decreased from two months of growth to three months of growth and increased slightly by the fifth month; the curve was similar to percent corm total sugar of Figure 2. A similar growth curve of percent total sugar calculated on the dry weight basis was observed in sweetpotato (26).

Corm starch content showed a slight increase towards the later part of the growing season (Fig. 2). Izawa and Okamoto (25) reported identical results in dasheen. Starch percentage on the dry weight basis was also reported to increase with time in sweetpotato (26) and potato (4, 10). The Duncan multiple range test (Table IX), however, indicated that the percent corm starch between harvest periods across varieties was different between only five and eight months of growth. There was no significant difference at the five percent level of starch percentage between the other periods of harvest.

The factors affecting percent corm starch and cormel starch and later applied to corm yield are presented in Tables XI-XV, XIX, XXIV-XXV, XXVI, XXX. Percent corm protein content as one of the factors was also interpreted as percent total nitrogen. The average protein content for the four cultivars calculated on the percent dry matter basis decreased with time. (Table X). The recommended time to harvest if interest is in percent protein or percent total nitrogen content would then be the early stages of growth (Fig. 2). The obtained protein contents for the four varieties studied here on the dry weight basis are higher than the values obtained by Payne, *et al*. (66) on four cultivars of air dried cooked taro. The protein values of the air dried cooked taro cultivars obtained by the same factor of 6.25 on total nitrogen from the Kjeldahl method were 1.75 percent, 1.85 percent, 1.91 percent and 2.36 percent for 'Piialii', 'Piko Uliuli', 'Lehua Palaii' and 'Mana Opelu', respectively.

The contribution of corm leaf weight, leaf area, leaf bulk, protein content of total nitrogen content of corms and cormels, specific gravity, the percent starch and sugar content of the corms and cormels to the variation of corm yield and corm and cormel starch content is presented in the regression-correlation section of the results.

Cormel yield is briefly considered here because the primary commercial interest is in the corm. Cormel weight increased with time (Table V) and the interaction of cultivar and time was not significant. Although the cormels of 'Lehua Maoli' were heavier there were fewer cormels. A producer interested in total yield then may want to try a variety such as 'Haakea' which has lighter cormels (Table V) but greater in number which would result in a higher total cormel yield than 'Lehua Maoli' which has heavier (Table V) but fewer cormels (Table IV). In terms of total weight of cormels 'Piko Kea', 'Haakea', 'Lehua Maoli' and 'Red Moi' would give the best yield respectively. If it were possible for a grower to remove only the corm during harvest leaving the cormels intact it may be advantageous since the data reveals that the cormels were increasing up to the last harvest (Table V).

The amount of variation, R^2, accounted for in corm weight by the variables in the first regression output (Tables XI, XII, XIII, XIV) and the significant partial regression coefficients (Tables XV, XVI, XVII, XVIII) are presented in the results. The values of the coefficient of determination for the first regression output for corm yield is greater than 50 percent in all of the cultivars. The coefficient of determination values of the selected significant variables in the stepwise regression analysis of the four cultivars are also greater than 50 percent (Tables XV, XVI, XVII, XVIII). The corm yields for each cultivar may be estimated by the partial regression coefficients provided in Tables XV to XVIII. The variation in the factors affecting the corm weight of the four cultivars may be due to the cultivar difference. The lack of a common group of factors affecting the corm yield of the four cultivars implies that there is insufficient information in this experiment to be able to estimate corm yield of the same cultivar grown in the same location.

As for the cultural aspect of corm weight, the corms unlike the cormels differed not only in size and weight but responded differently with age. 'Haakea' and 'Red Moi' appear to be late or slow growing cultivars under the growth conditions present at the Waimanalo Experiment Station (Table VI). Corm weights increased slowly but continued to do so to the last harvest period. The weight gains made by 'Piko Kea' and 'Lehua Maoli' were higher in the early stages of growth than 'Haakea' and 'Red Moi'. The early weight gains made by 'Piko Kea' (Table VI) reached its maximum earlier than the rest of the varieties, somewhere between eight and nine months. 'Piko Kea' which is usually grown under paddy conditions, is normally a later cultivar, maturing in fifteen to eighteen months (80). 'Piko Kea' which makes its best growth in the cooler parts of the island did not do well under the hot dry land conditions of the Waimanalo Experiment Station and consequently its time of maturation was shortened.

'Lehua Maoli' reached its maximum corm weight at 10 months (Table VI). Under the growth conditions of the experiment station the best time to harvest 'Lehua Maoli' would be somewhere between nine and ten months. The maturation interval of 'Lehua Maoli' coincides with that of Whitney, et al. (80) who stated that the period of maturation is between eight and twelve months. 'Lehua Maoli' is a cultivar that does well under both dry land and wet land conditions and therefore did not experience to great a change in maturation rate as did 'Piko Kea'. 'Haakea', a taro adapted to both dry and wet land conditions normally matures in nine to twelve months (80).

Interest in the corm weight or total plant yield of corms and the best time to harvest for the most economical gains would be from nine to ten months of growth for 'Lehua Maoli'. The variety 'Piko Kea' if planted under dry land conditions such as the Waimanalo Experiment Station, should be harvested between eight and nine months of growth. Holding the corm in the ground did not increase the size of the corm appreciably and it may subject the corm to possible physical and biological damage. Greater yields would be attained if 'Haakea' and 'Red Moi' were harvested at eleven months or later.

Interest in estimating the percent corm and cormel starch content from the data collected resulted in the correlation-regression analysis presented in the results. Like corm yield the factors used accounted for 50 percent or greater of the variation in corm and cormel percent starch in the first regression output. The factors selected as significant contributors to percent corm starch content in the stepwise regression (Tables XX, XXI, XXII, XXIII) accounted for 50 percent or more of the variation except for 'Lehua Maoli'. The R^2 value of 'Lehua Maoli' was .179.

The significant factors in the stepwise regression analysis of percent cormel starch content accounting for 50 percent or more of the variation was found in all of the cultivars but 'Red Moi'. In both corm and cormel percent starch content, corm and cormel starch content was a common significant factor. Table XXXV reveals that corm and cormel starch content are correlated in all of the cultivars and that corm and cormel starch may not be physical entities. Like corm weight it is doubtful whether corm starch and cormel starch content could be determined or controlled by the factors provided by this one experiment.

TABLE XXXV. CORRELATIONS OF CORMEL STARCH ON CORN STARCH

Cultivar	R	R^2	b	t
Haakea	.862**	.743	1.1527	8.67**
Piko Kea	.527**	.278	0.5251	3.16**
Red Moi	.540**	.291	0.9983	3.27**
Lehua Maoli	.424**	.179	0.4893	2.38*

Corm and cormel specific gravity was not different between cultivars and not affected by the interaction of age and cultivar.

The percent corm starch content was not correlated to corm specific gravity in all varieties but 'Red Moi'. The correlation coefficient of percent corm starch to corm specific gravity was .6673**. The use of specific gravity to determine total solids in potatoes is well known. However, the use of specific gravity as a measure of starch contents has its limitations. In storage, the measure of starch content of potato is good only during the early phases of storage and becomes unreliable with time because of the physiological change during storage (24). Aside from total solids and water that affect specific gravity in potato, Porter, et al. (67) suggested that tissue air space and other unknown factors affect specific gravity. Interest in using corm specific gravity as a measure of taro starch content would then involve more then the scope of this thesis.

From the results discussed the following recommendations can be made: to be able to estimate and control the quality of the corm contents and weight more investigations must be made on the physiology of taro. The organic constituents of the leaves such as total sugars, reducing sugars and non-reducing sugars during growth must be related to the growing corm. To eliminate the effects of seasons, plantings should be made monthly. To use specific gravity as a measure of starch content percent moisture and total solid data must be taken to eliminate their affect on specific gravity.

SUMMARY

The development of the number of cormels, corm leaf area, leaf weight, leaf bulk or top growth, corm and cormel weight, sugar, starch and protein content were investigated over a seven month growth period of four taro cultivars, 'Haakea', 'Piko Kea', 'Red Moi', and 'Lehua Maoli'. Starch, total sugar and Kjeldhal protein were calculated on the percent dry weight basis.

Corm production and top growth were recorded from five months to eleven months of growth. The average corm weight for all of the cultivars increased steadily from five to eleven months of growth. 'Piko Kea' unlike the other cultivars increased its corm weight only up to seven months of growth. 'Lehua Maoli' had the heaviest corm and 'Red Moi', 'Haakea' and 'Piko Kea' had decreasing corm weight, respectively.

Cormel production for all of the cultivars increased with time without stopping in the eleven month growth period. Cormel weight increased by cultivar in this order: 'Lehua Maoli', 'Piko Kea', 'Haakea', and 'Red Moi'. Cormel number per plant increased in 'Piko Kea' and 'Haakea' but reached their maximum in 'Lehua Maoli' and 'Red Moi' by the end of nine months of growth.

Although corm weight increased steadily from five to eleven months, top growth or leaf bulk increased from one to seven months of growth and decreased from seven to eleven months. The reduction in leaf bulk was due to a reduction in corm leaf area, corm leaf weight,

and no further increase in leaf number. This decrease in leaf bulk was also accompanied by a reduction in plant height.

Corm starch content was found to increase slowly in all of the cultivars from five to eleven months. 'Lehua Maoli' and 'Red Moi' were not different in percent starch content. 'Piko Kea' and 'Haakea' were not different in percent corm starch content, but as a group they had less starch than 'Lehua Maoli' and 'Red Moi'.

Cormel starch and corm starch contents were highly correlated, suggesting that they are not separate entities. There was no interaction between the four cultivars and time in percent starch content in the cormels and the corms. Cormel starch content by cultivar was highest in this order: 'Lehua Maoli', 'Red Moi', 'Piko Kea' and 'Haakea'.

Corm and cormel specific gravity were correlated to corm and cormel starch content to investigate the use of specific gravity as an estimate of starch content. Specific gravity was correlated to the corm starch content of 'Red Moi' only. It was concluded from the data of this thesis that specific gravity is not a good estimate of starch content.

Corm and cormel sugar content had similar curves. Both decreased from five to six months of growth before increasing again slowly up to eleven months of growth.

The general growth curve of corm protein was found to decrease with time, and the best time to harvest for protein would be the early stages of growth, at five to six months. There were significant differences between cultivars in corm protein content: 'Lehua Maoli', 3.2 percent; 'Piko Kea', 4.3 percent; 'Haakea', 4.2 percent and 'Red Moi', 3.4 percent.

The general growth curve of cormel protein content of all of the cultivars was found to decrease with age. Cultivar differences in protein content were found significant.

Correlation-regression analysis with the data collected to estimate and control the quality and corm and cormel weights revealed that the data provided by this thesis were insufficient to make such a determination.

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